THE NATURE CONSERVANCY NEWS

September/October 1984

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DESERT AQUATIC SYSTEMS

Desert — but not deserted.

Robert C. Simpson

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VOLUME 34, NUMBER 5
SEPTEMBER/OCTOBER 1984

THE NATURE CONSERVANCY NEWS

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COVER: Water in the desert—the Amargosa River near Death Valley, California. The Conservancy recently secured an option to purchase 400 riverside acres. Photo by George Service.

The Nature Conservancy is a national conservation organization committed to the preservation of natural diversity by protecting lands and waters supporting the best examples of all elements of our natural world.

To date the Conservancy and its members have been responsible for the preservation of 2,276,287 acres of forests, marshes, prairies, mountains, deserts, and islands: home to rare and endangered species of wildlife and plants. 3,469 projects have been completed since the acquisition of the first preserve in 1954. Approximately 60% of all preserves are retained by the Conservancy and managed by staff and volunteer land stewards.

A membership organization, the Conservancy was incorporated in 1951 in the District of Columbia for scientific and educational purposes. The Nature Conservancy is a nonprofit, tax-exempt corporation under Section 501(c)(3) of the Internal Revenue Code and is a publicly supported organization as defined in Sections 170(b)(1)(vi) and 509(a). All contributions are tax deductible.

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The Nature Conservancy

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George Service

Coachella Valley Preserve, California

President's Letter

IN THE DESERT, plants and animals survive because they have evolved adaptations to extreme drought. The desert tortoise, for example, converts some of its food to water, which is stored for the hottest months in two sacs under its domed shell. Cacti also store water—in their stems. And one of the desert's most remarkable creatures, the kangaroo rat, survives by recycling virtually all of its body fluids. For many species, however, life in the desert is possible only in or near oases—the few scattered sites where groundwater meets the surface in springs or pools.

Though relatively unknown, these aquatic systems are critical to many organisms, including a number of rare species. For example, approximately 74 percent of the fish species federally listed as threatened or endangered survive in desert springs and pools. Many plant and invertebrate species also have evolved in these isolated and restricted habitats.

As human populations grow and land pressures increase, the demands on arid areas for development and agriculture rise as well. Because water is at a premium in the desert, its increased use could spell total disappearance of desert aquatic habitats. So many such oases have been destroyed that we consider them to be among North America's most endangered ecosystem types. Many of the groundwater discharge areas that are not completely devastated have been seriously altered by grazing, toxic pollutants, the introduction of exotic species, or by lowering of the water table.

But there is hope. Through its National Wetlands Conservation Project—a five-year, $50-million-plus effort begun in early 1983 to preserve water-related ecosystems in the United States—The Nature Conservancy has succeeded in protecting highly significant desert aquatic habitats at Ash Meadows, Nevada, and in the Coachella Valley, California. The program was initiated by a $25-million challenge grant, the largest ever made by a private foundation for conservation purposes, from the Richard King Mellon Foundation.

In addition to these two systems of Southwestern desert springs, the Conservancy has protected other vital wetland areas through the National Wetlands Conservation Project. They include rare plant sites and shorebird nesting habitat at Block Island, Rhode Island; prairie potholes in the Dakotas (important to breeding and migratory waterfowl); and critical habitat for migrating sandhill and whooping cranes along the Platte River of Nebraska.

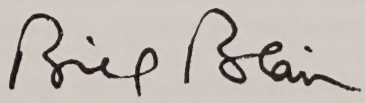
What we have done so far is only the beginning. Our goal is nothing short of ensuring protection for the largest and best of our nation's threatened aquatic resources.

The Conservancy has consolidated information from natural heritage programs nationwide to set priorities for its National Wetlands Project. If funding can be identified, the Conservancy hopes to begin working to preserve many other threatened aquatic systems. Among them are the last undisturbed marshes along the south shore of Lake Erie, headwaters of parts of the upper Colorado River Basin, critical habitats along the southern New England coast, freshwater wetlands of California's Central Valley, uncommon aquatic communities of New Jersey's Pine Barrens, and the hardwood bottomlands of Arkansas's White River system. The Chesapeake Bay area—once our nation's most productive estuary—is also slated for conservation action.

In this issue of *The Nature Conservancy News,* we celebrate the protection of desert springs at Ash Meadows and Thousand Palms Oasis in the Coachella Valley. At the same time, we celebrate the success of our continuing partnership with the Richard King Mellon Foundation. We are deeply grateful to the foundation for joining us in this tremendously ambitious effort. We also wish to thank all those others who have supported our efforts to preserve Ash Meadows and Thousand Palms, especially the Goodhill Foundation.

Our National Wetlands Conservation Project is not yet two years old. The Conservancy expects to use and re-use the Mellon Foundation grant over the next five to ten years to help preserve wetlands worth at least $50 million. It will do so by fund raising; by encouraging gifts of land, matching gifts, and bargain sales; and by reselling land to government conservation agencies. In so doing we hope not only to save some of the country's most important aquatic systems, but also to form new partnerships for continuing wetlands preservation with private and public organizations and individuals across the country.

We can do this job. But we will need everybody's help.



William D. Blair, Jr.

Dennis Kubly

Desert Waters: Past, Present, and Future

by Dean A. Hendrickson and Dennis M. Kubly

FROM EARLY SETTLERS to modern highway travelers, Americans have maintained a perplexing and dichotomous attitude toward our nation's deserts. We revel in the natural splendor and raw beauty of this vast region of rock and sand, yet decry its barrenness. We condemn it as wasteland, yet seek at every opportunity to convert its natural resources into marketable productivity. The incongruity of our actions has led to the growth of major Southwestern metropolitan areas sustained by supplies of water far exceeding what the desert could naturally provide. So it is that some of the region's natural resources—desert aquatic ecosystems that evolved over millions of years—have been disappearing at an alarming and accelerating rate.

The relatively well-studied desert fishes are a valuable indicator of the general health of these ecosystems. Of 31 fishes listed as endangered by the U.S. Fish and Wildlife Service in 1981, 23 are desert species; others are continually being added to the list. The figures are especially revealing when we consider that desert aquatic ecosystems represent a miniscule proportion of this country's total aquatic resources.

Species of western North America have been evolving in isolation from those of the eastern part of the continent since as long ago as 100 million years, when a seaway extended far north from the present Gulf of Mexico and covered the western half of the continent. The shallow sea receded as the Rocky Mountains began forming, essentially dividing the land mass we call North America. Although relative geologic stability prevailed east of the Rockies, land to the west underwent major periods of mountain building, vulcanism, erosion, and folding and faulting of the earth's crust. A distinctive topography of parallel basins and

Robert C. Simpson

Dean Hendrickson

John Gerlach

Opposite: America's largest desert river, the Colorado, on its run through Marble Canyon, Arizona. Top left: Gila chubs, rare desert fish that flourish at the Conservancy's Canelo Hills Cienega Preserve near Tucson. Left: desert spring in the Mexican state of Chihuahua. Above: the black toad, whose entire world population is restricted to a few square miles in the Mojave.

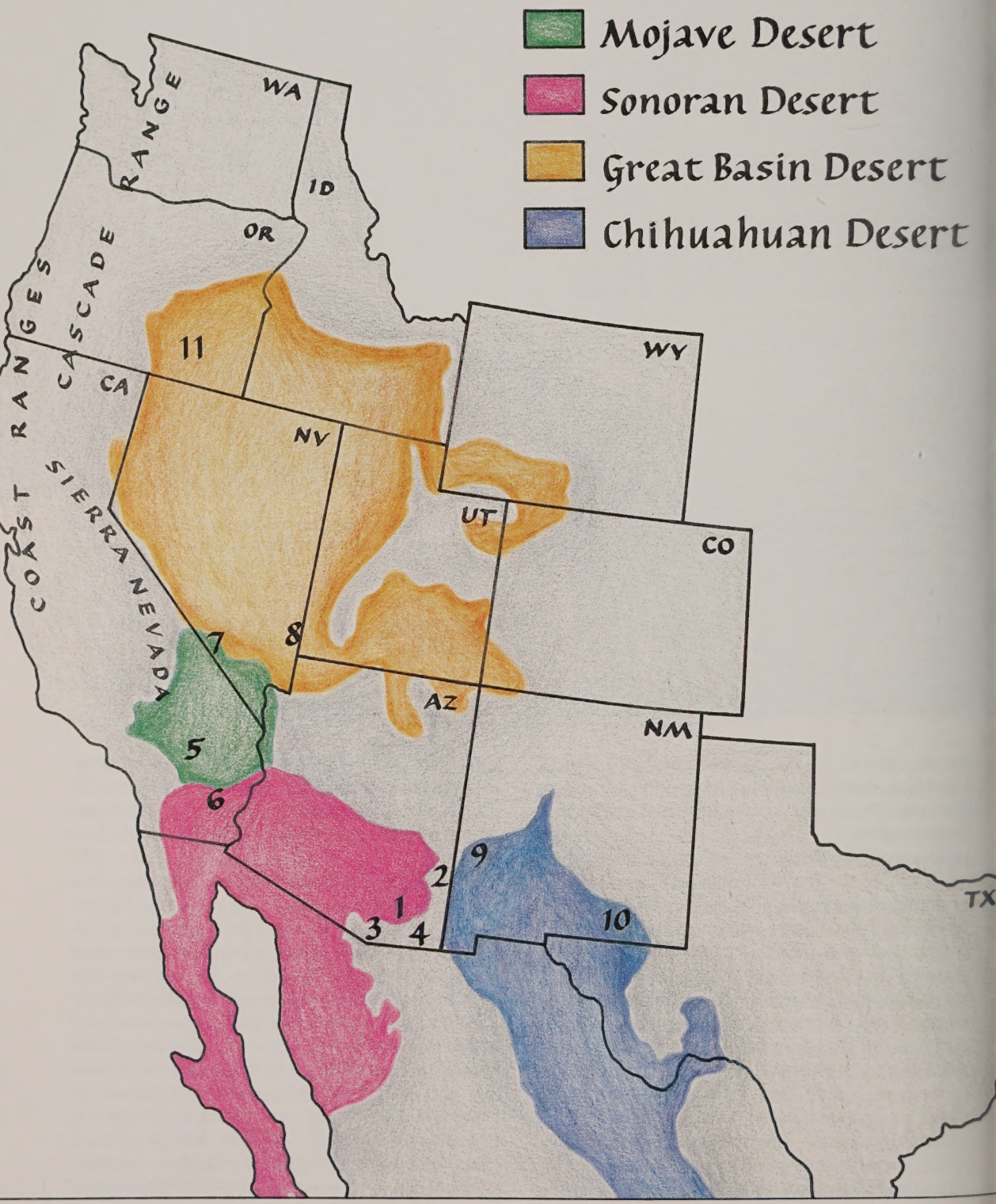
ranges, caused by mountains rising and valleys subsiding, began developing some 30 to 15 million years ago. It still characterizes much of our present desert regions.

The major uplifting, ten to less than five million years ago, of the Sierra Nevada and coastal ranges to the west began to block the eastward flow of moist Pacific air, thus isolating the basins and ranges and initiating the formation of regional deserts. The development of our modern deserts was interrupted, however, when moister environments of the Pleistocene Ice Ages formed lakes in hundreds of interior valleys. Many would persist today were it not for the effect of a regional long-term drying trend that turned them into "dry lakes" or "playas" (desert basins having no outlets). Other basins were drained by erosional incision caused by through-flowing streams.

As the deserts expanded, desert-adapted terrestrial organisms, which may have been evolving for millenia in localized arid pockets, increased their ranges. In contrast, aquatic habitats dwindled rapidly to become watery islands in seas of deserts.

THE GREAT BASIN actually consists of a series of closed basins, the most familiar being Death Valley. Its floor bears a large saline playa that receives runoff water only from occasional thunderstorms and from the outflows of a few springs. Looking out over this vast salt flat, it is difficult to imagine a lake 90 miles long and over 600 feet deep. But such a body of water (Lake Manly) existed during, and for some time following, past pluvial or wetter periods thousands of years ago. Then it was not isolated as the modern playa but was, instead, a link in a chain of lakes connected by rivers originating in distant mountains.

Major North American Deserts



Joan Pennington

Conservancy preserves protecting desert wetlands:

ARIZONA

1 **Canelo Hills Cienega.** 232-acre spring-fed marshland; critical habitat for numerous plant and animal species including Gila chub, banded rock rattlesnake, and *Spiranthes graminea,* an orchid that occurs on only one other U.S. site.

2 **Muleshoe Ranch.** 51,380 acres of rolling hills and desert canyons bearing clear spring-fed streams; home for *Gila intermedia,* proposed for federal listing as a threatened fish species.

3 **Patagonia-Sonoita Creek Sanctuary.** Year-round stream lined with cottonwoods. Habitat for the federally endangered Gila topminnow and abundant and diverse birdlife. 312 acres.

4 **Ramsey Canyon.** A deep gorge, temperate and moist in contrast to the surrounding desert. Well-known among birders for its many rare and peripheral birds. 300 acres.

CALIFORNIA

5 **Big Morongo Canyon.** Desert spring providing food, cover, and water for some 300 bird species. The Conservancy owns 80 acres and manages the adjacent 3,840 acres in cooperation with BLM and San Bernardino County.

6 **Coachella Valley Preserve.** 2,083 acres include Thousand Palms Oasis and sand dunes supporting the federally threatened Coachella Valley fringe-toed lizard. (See page 18).

NEVADA

7 **Ash Meadows.** 12,613 acres (most of which have been transferred to U.S. Fish and Wildlife Service) shelter more than 20 endemic plants, fish, and invertebrates that occur nowhere else on Earth. (See page 13).

8 **Condor Canyon.** 40 acres at the head of Condor Canyon include a stream that harbors three rare endemic fish species: Panaca Big Spring spinedace, a speckled dace, and a desert sucker.

NEW MEXICO

9 **Gila Riparian Project.** 196 acres of lush gallery woodlands along Gila River and Mogollon Creek; among the 265 bird species sighted here are peregrine falcons and Gila woodpeckers.

10 **Rattlesnake Springs.** Riparian desert oasis nourished by 13 springs; important breeding site for Eastern bluebirds, orchard buntings, hooded orioles, vermilion flycatchers, and long-billed marsh wrens. 9 acres.

OREGON

11 **Borax Lake Preserve.** Home of endangered, endemic Borax Lake chub; lease on 160 acres.

Playas are abundant in basin and range regions of Nevada, California, and Utah and in the Mexican states of Chihuahua and Coahuila. Similar dry lakes, between 20 and 30 thousand, dot the vast Llano Estacado or "Staked Plains" tableland of eastern New Mexico and western Texas. These arid flats hardly seem a suitable environment for aquatic life. Yet, periodic thunderstorms produce sufficient runoff to temporarily fill shallow playa lakes. These waters provide a hatching stimulus for drought-resistant and salt-tolerant eggs of such organisms as fairy shrimp, clam shrimp, tadpole shrimp, and water fleas. Amazingly, the eggs have lain dormant, preserved in the sun-baked mud. As the playa's waters evaporate, the adult invertebrates perish, but not before producing more eggs. This cycle, one that has been occurring for millions of years, is repeated when the dry lakes again fill with water.

During periods of bird migration, playa lakes also serve as resting and feeding sites for numerous species of waterfowl, waders, and shorebirds. Little is known of the habits or numbers of birds that use the basin and range lakes. However, on the Llano Estacado, the temporary playa lakes help to support waterfowl numbering in the hundreds of thousands.

The fate of Lake Manly in Death Valley was shared by more than 200 pluvial lakes in the basin and range region. Some basins, however, did not dry out completely because they still received sufficient runoff from mountain streams and springs. Today these valleys contain remnant, perennial lakes—dwarfed in size relative to their pluvial predecessors and in some instances considerably more saline. The high salinity (two to five times that of seawater) of some perennial closed-basin lakes—such as Great Salt Lake, Utah, and Mono Lake, California—greatly restricts the diversity of aquatic species. No aquatic vertebrates exist in these lakes, but the well-adapted brine shrimp *Artemia* and brine fly *Ephydra* are found in Mono and Great Salt Lakes. These prolific invertebrates serve as important food resources for lake-dwelling birds, particularly gulls.

Fossils in sediments of many former lakes indicate that fish diversity has decreased dramatically as aridity has increased in the basin and range region over the past few million years. Today, only a few natural desert lakes, notably Pyramid Lake and others in the Lahontan Basin of western Nevada, provide hospitable environments for fishes. The prehistorically more widely distributed and now endangered cui-ui sucker persists today only in Pyramid Lake.

Many desert fish species today are confined to isolated springs where they have persisted at least

Dennis Kubly

Dusk at Soda Dry Lake—a "playa" or closed desert basin in San Bernardino County, California.

since the drying of pluvial lakes. Compared with desert lakes and streams, the springs are relatively stable habitats, largely because they are fed by massive groundwater reservoirs that are little affected by variations in precipitation. Furthermore, the springs' physical isolation prohibits either genetic exchange with or recolonization by fish populations living elsewhere, always possibilities in stream systems.

Species have evolved in these isolated bodies of water into endemic forms known only from single springs or related spring complexes. The springs of Death Valley and nearby Ash Meadows as well as the Bolson de Cuatro Cienegas, are noted for their endemic faunas, including species and subspecies of pupfishes and numerous, little-studied endemic snails.

Cuatro Cienegas in Coahuila, Mexico, is a much-researched spring complex of considerable interest to biologists and conservationists. Its aquatic habitats include marshes, numerous springs (most are thermal), constant streams, saline playa lakes, and spring pools or sinkholes (locally called *pozos*). More than half of the basin's 20 native fishes are found nowhere else, and it harbors the most spectacular array of endemic snails known in the Western Hemisphere.

In addition to springs and playas, our four deserts are replete with stream courses, but the majority are intermittent to ephemeral. Even major rivers draining large areas, such as the Gila of Arizona and New Mexico, naturally disappeared into the sand before reaching their mouths. Until only about a century ago, however, perennial waters on valley floors were much more extensive, maintained by higher water tables and by marshland communities or *cienegas*.

ALWAYS SUBJECT TO GEOLOGIC and climatic influences, aquatic habitats of the North American deserts have changed dramatically over the past tens of millions of years. Although extinction rates of organisms have been high, these natural alterations were not so rapid that they prevented species from evolving adaptations to their changing environments. In contrast, human activities spanning the past 100 years alone have done perhaps as much to alter desert aquatic ecosystems as did the geologic effects that lasted half a million times longer.

Actually, human manipulation of these habitats long predates the past century, but it had only localized effects. The history of the Sonoran Desert exemplifies such regional impact. Here, from 300

B.C. to 1450 A.D., the Hohokam Indians built elaborate canal systems to support their agricultural irrigation. They may have used nearly the entire summer discharge of the Gila River near what is now Phoenix, Arizona. After this group mysteriously disappeared, the Pima Indians colonized the area and, as reported by 16th century Spanish explorers, continued extensive irrigation along most major Sonoran Desert waterways. Spanish missionaries expanded this practice; they also introduced domestic livestock.

Early Spanish journals, as well as middle-to-late 19th-century accounts by American explorers and settlers, depict most Sonoran Desert aquatic systems as very different from those now prevalent. Streams and rivers flowed through vast desert oases of riparian forests and marshes. Beaver dams were abundant, large edible fish were plentiful, and streamside grasslands fed the livestock of weary travelers. Water issued reliably over many miles of stream courses where it is now found only (and rarely) after major storms. It was not until late in the last century that significant changes in these aquatic systems became evident.

Roughly after 1860, the altering of watersheds and the damming and diverting of stream flows accelerated. By the 1890's, the impacts of alterations were dramatically apparent. An 1892 drought in Arizona combined with already severely overgrazed ranges to cause catastrophic losses of cattle. About the same time, the much-analyzed but still poorly understood cycle of "arroyo cutting" began. Whether this was triggered by overgrazing, increasing aridity in the region, road building, water diversion, fires, or any combination of these events, the desert waterways of much of the Southwest were changed extensively. Within a few decades, streams that once flowed dependably through lush cienegas on valley floors were eroded to deep gashes in the earth. Stream flows became far less predictable, and watercourses were transformed into broad and barren sandy or gravelly beds isolated from desiccated valley floors by vertical walls as high as 30 feet. In the process, much riparian vegetation was left high and dry. All that remains of the marshlands that once surrounded the rivers are occasional layers of dark organic soils, visible in arroyo walls many feet above the present streambed. Moreover, in modern watercourses, normally

J. Rorabaugh

J. Rorabaugh

At left: the Eastern bluebird at its only breeding site in New Mexico—the Conservancy's Rattlesnake Springs Preserve. Above: Patagonia-Sonoita Creek Sanctuary, a Conservancy stronghold in the Upper Sonoran Life Zone.

dry streambeds undergo violent and short-lived flash floods because a decrease in terrestrial vegetation (due to over-grazing) and other modifications have increased runoff rates. In addition, cienegas, natural sponge-like reservoirs, are no longer present to soak up runoff peaks and release stored water over long periods of time.

Although arroyo cutting greatly concerned residents at the time and was widely publicized, most desert dwellers today are unaware of the vast changes that occurred during the end of the 19th century. They are astounded to learn that lush oases once lined desert waterways. Since most human populations of the Southwest are now concentrated in metropolitan areas, the many miles of stream flows long since vanished into desert sands are no longer necessary for modern human life in the desert. These waters have been captured and impounded in massive storage reservoirs. Exploitation of desert waters continues to mount and, as supplies are depleted, irrigation pumps pursue water to ever-increasing subterranean depths. Many large springs, especially in the Mojave and Chihuahuan Deserts, have been completely dried or their discharges greatly decreased by pumping of their aquifers (often from a distant location). Some cottonwood, sycamore, ash, and willow riparian galleries and mesquite forests, which survived arroyo cutting, are disappearing because water tables have dropped to inaccessible depths. Other woodlands were cut for fuel or removed in clearing projects intended to reduce water consumption by these deep-rooted plants.

ALTERATION OF AQUATIC habitats extends from desert streams to major river systems whose discharges are retained and "managed" in chains of reservoirs. Our largest desert river, the Colorado, is confined by massive impoundments both above and below the Grand Canyon. In addition, the last 400 miles of its passage are highly regulated, channeled, and diked. Water flowing to Mexico is usually highly saline and greatly diminished in volume. Having once discharged nutrient-rich waters to the Gulf of California, the Colorado had for decades not been allowed to flow to the sea until recently—a situation that surely affected the Gulf's productivity.

The unique Colorado River fishes are nearing extinction. Their former riverine habitats are largely inundated by reservoirs that block the fishes' movements. Where rivers do persist, their seasonal discharge and temperature patterns are altered and controlled. Nor are any of the native fishes adapted to thrive in the abundant reservoirs. These new environments harbor introduced fishes—predators and competitors with which the native fauna is not equipped evolutionarily to coexist.

The Colorado is not unique in being a modified desert river. All 18 known native fishes of the Gila River system have been affected not only by eight major dams but by exotic species, arroyo cutting, misguided land management practices, and groundwater pumping. One species now is extinct; five are federally listed as endangered, three as threatened. Two more have been recently proposed for federal protection. Five are extirpated in the Gila River drainage, and populations remain only in other parts of the Colorado River system—where at least two of them have failed to reproduce successfully during the past few decades. An even larger number of native fish extinctions has occurred in the Rio Grande, and the problem extends far beyond our national borders.

Ironically, even the desert playas, long bypassed as wastelands, now have caught the eye of developers equipped with new technologies. Some have become the playgrounds for destructive off-road vehicles and mineral collectors. Many occur within major military reservations supporting varied activities, including space shuttle landings and nuclear weapons testing. They are prime candidates for missile installations, hazardous chemical repositories, and nuclear waste sites.

In their almost infinitely brief tenure in the North American desert, humans have already eclipsed much of what millions of years of natural history have produced. It is obvious that development such as the region has known in the past few decades cannot continue indefinitely. Ironically, the ever-powerful pressure of economics, rather than water shortages, may contribute most to preserving North America's desert aquatic ecosystems. Eastern taxpayers are increasingly reluctant to finance massive western water-development projects, as they reliably have done in the past. With the burden of paying for these endeavors beginning to fall on the citizens of the Southwest, many projects may be dropped because their promoters cannot afford the costs. What is being lost is largely a non-renewable resource. As a result of our drive for short-term profit, we may leave future generations with a debt that can never be repaid. Ultimately, water will be the limiting factor.

Dean A. Hendrickson and **Dennis M. Kubly** are both doctoral candidates in the Department of Zoology at Arizona State University. Both have been involved in researching varied aspects of aquatic ecosystems in the Mojave, Sonoran, and Chihuahuan Deserts. The authors wish to thank their reviewers: Drs. Gerald A. Cole, Paul C. Marsh, Edwin P. Pister, and W. L. Minckley.

Susan Cochrane

Bright Future for a Desert Refugium

by Anne Schwartz

IN A REMOTE CORNER of the Nevada desert, rare plants and fish have prevailed over condos and casinos. Last February, after more than a decade of struggle, The Nature Conservancy purchased from a real estate developer 12,613 desert-wetland acres in the unique Ash Meadows area. The preservation of this oasis in the Mojave Desert was made final this past summer, when the Conservancy turned most of the land over to the U.S. Fish and Wildlife Service, which will manage it as a wildlife refuge. (The remaining acreage will be transferred to the agency this fall.) Protection of this remarkable tract, biologically one of the most important areas on the continent, will save from extinction nearly two dozen plant and animal species found nowhere else on Earth.

To the uninitiated, Ash Meadows might seem an unlikely place for a wildlife refuge. Seventy miles northwest of Las Vegas, just east of Death Valley, it totals 40,000 acres in the Amargosa Valley and receives less than three inches of rainfall in an average year. But Ash Meadows is a major discharge point for a vast underground aquifer stretching 100 miles to the northeast, and it provides a rich and complex variety of habitats.

In the eastern uplands, the water-bearing strata come to the surface in a line of more than 20 seeps, streams, and lime-encrusted pools. North and west is Carson's Slough, through which all the meadows' water eventually drains, while in the southern and western part of the oasis are sandy dunes. Scattered throughout are alkali barrens,

spots in which water was once prevalent and in which repeated evaporation has left deposits of whitish alkaline salts. Virtually all of the water at Ash Meadows is "fossil" water, believed to have entered the groundwater system thousands of years ago.

Ash Meadows contains, for its size, the highest number of endemic species in the continental U.S. —more than 20 plants and animals that occur nowhere else. Seven endemic plants have been proposed for federal listing as endangered species. Four fish (two species, two subspecies), each restricted to a few springs at most, are classified as endangered throughout their limited ranges. The springs are also home to several extremely rare insects and a diversity of freshwater snails, only a few of which have been scientifically described and named.

THE HISTORY OF ASH MEADOWS' unusual concentration of endemics begins at the end of the last Pleistocene Ice Age, about 8,000 to 12,000 years ago. During that period of extensive glaciation, much of the Southwest was covered by large, interconnected lakes and rivers. Climatic changes associated with the receding of the glaciers caused the lake levels to fluctuate. Shorelines moved back

A sampler of Ash Meadows' flowering plants: alkali mariposa lily (top), native to the Mojave Desert; spring-loving centaury (at right) and Enceliopsis nudicaulis *var.* corrugata *(above)—both candidates for federal listing as endangered species.*

photos by Susan Cochrane

and forth, leaving deposits of soils and carbonate-rich minerals, and groundwater rising to the surface and evaporating left limestone deposits.

The overall environment, once moist and cool, changed to the warm, arid conditions that now prevail. With retreat of the glaciers, lake habitats dried and most fish species became extinct. A few, however, were able to survive in the shallows and outflows of the spring-fed pools left as the lakes receded. These fish populations were isolated on aquatic "islands" in a sea of desert. At Ash Meadows, the populations were effectively segregated from each other in pools lying, in some cases, only a few hundred yards apart.

Such continued isolation resulted in the evolution of several endemic fish species. The best known is the tiny Devil's Hole pupfish, *Cyprinodon diabolis*. Its only population, which fluctuates between 150 and 700 individuals, lives in a deep spring-fed pool in a limestone cavern in a mountainside, 50 feet below the desert floor.

The Pleistocene also set the stage for the uncommon plants at Ash Meadows. The glaciers' advance southward caused northern plant species to gradually retreat to the south as well. Then, when the glaciers eventually receded, species that survived the warming climate either repopulated more northern areas or shifted to higher elevations. But the springs and associated cooler microclimate of Ash Meadows made it possible for some of the northern flora to persist there. Thus, Ash Meadows became a refugium for certain plants. As these species adapted to the hotter climate and the dense salty soils left by the receding lakes, they evolved into species and varieties distinct from their northern relatives.

In the rarity of its habitats, its isolation, and its resulting concentration of endemics, Ash Meadows has frequently been likened to the Galápagos Islands. Like the Galápagos, Ash Meadows is a natural laboratory for the study of evolution. Scientists are studying the area's fish species for evidence they may yield about evolutionary processes. Because they appear to have evolved relatively quickly, the fish seem to support the recent theory of punctuated equilibrium, which holds that evolution occurs not gradually, but during bursts of rapid change.

WHILE THE PUPFISH have brought Ash Meadows its greatest public recognition, the flora is of extreme interest to scientists. In all, about 200 plant species are found in the oasis, some occurring at their geographic limits.

The slightly higher elevations are dominated by such low, shrubby plants as shadscale and saltbush. Around springs and where the groundwater is close to the surface are the rare ash-mesquite forests. These consist of small scattered groves of leatherleaf ash (*Fraxinus velutina* var. *coriacea*), which gives the oasis its name, and patches of screwbean mesquite (*Prosopis pubescens*), a plant that not long ago was extensive in the area. Marshy sites support meadows of sod-forming saltgrass and rushes.

Several of the plants that are candidates for endangered status are found alongside Ash Meadows' springs and streams. Here grow the spring-loving centaury (*Centaurium namophilum*)—a delicate, pink-flowered plant—and the Ash Meadows gumplant (*Grindelia fraxino-pratensis*), a tall composite with golden-yellow flowers.

Several rare plants are found on the alkali barrens, including the Ash Meadows ivesia (*Ivesia eremica*), a low-growing species with gray leaves and small white flowers, and *Enceliopsis nudicaulis* var. *corrugata,* a composite producing yellow flowers on stiff, leafless stems. The Ash Meadows blazing star (*Mentzelia leucophylla*) and the Ash Meadows milkvetch (*Astragalus phoenix*) also are endemic to the barrens. The flats at the south end of Carson's Slough support the Amargosa niterwort (*Nitrophila mohavensis*), which flourishes only in these highly saline soils.

Botanists and conservationists concerned about Ash Meadows remark on the subtle beauty of the area. It is most spectacular in the spring, with phacelias, sunflowers, and pincushion flowers blooming in shades of purple and yellow. The plants around the springs, typical of marsh flora, bloom in late summer and early fall; and in fall, the saltbush scrub turns golden-orange and the ash trees gold.

UNTIL RECENTLY, Ash Meadows has seen relatively little human interference. The Death Valley Expedition, the first scientific excursion to explore the area, came through in 1891 and made the first botanical collections. Over the next 100 years, the oasis was occasionally settled by homesteaders, whose abandoned shacks are testimony to the futility of farming the salty soils. It was also a hideout for outlaws and, in later years, home to houses of prostitution.

The first major loss of habitat occurred in the 1960's, when Carson's Slough was drained and mined for its peat. Drainage of the slough destroyed habitat for endemic plants, fish, and invertebrates, as well as for migrating waterfowl. This wetland's pollen record, which could have been of value to scientists seeking to determine the flora that existed in past eras, was also lost.

In the late 1960's, a mechanized agricultural operation began at Ash Meadows. Undiscouraged

Tom Baugh

by previous failures to farm the oasis, a company called Spring Meadows, Inc., bought about 12,000 acres of land in the water-rich northeastern part of Ash Meadows and, intending to raise cattle, started drilling wells to irrigate pasture and hay meadows. It burned and plowed large tracts of native vegetation, including 80 acres of screwbean forest.

By 1970, groundwater pumping by Spring Meadows had dangerously lowered the water level in Devil's Hole, imperiling the pupfish. The 43-acre Devil's Hole has been under the jurisdiction of the National Park Service since 1952, and its endemic pupfish is now protected under the Endangered Species Act.

The Park Service at first tried to negotiate groundwater use with Spring Meadows but was eventually forced to take the company to court. The government then won a series of decisions culminating in a 1976 Supreme Court ruling that required the establishment of a minimum allowable water level for Devil's Hole.

The Supreme Court decision did not concern any pupfish other than those at Devil's Hole and applied only to agricultural use of water. All through the litigation proceedings, Spring Meadows increased its groundwater pumping. Once the minimum water level was set, in 1978, the company put its farm up for sale. It was initially offered to the U.S. Fish and Wildlife Service, which chose not to purchase the land. Spring Meadows finally sold the land to Preferred Equities Corporation, a Las Vegas real estate company that had recently developed a desert area east of Ash Meadows.

Preferred Equities envisioned a resort at Ash Meadows—offering vacation homes, golf courses, casinos, and lakes in the desert—to be called Cal-Vada Lakes. It also had plans for light industry and farming. The development company requested, and the county approved, subdivisions for 20,000 houses. Then it began building roads, some across rare plant habitats, and enlarging pools and diverting their outflows.

Having evolved in isolation over thousands of years, the endangered Devil's Hole pupfish hangs on in a single spring-fed pool below the desert floor at Ash Meadows.

It became clear that if development were to proceed as planned, groundwater would become depleted in the not-too-distant future and species would be lost. Numerous organizations, including the Desert Fishes Council, the Northern Nevada Native Plant Society, and the Ash Meadows Education Fund, had been trying for years to preserve the oasis through regulatory means but had met with resistance from the seller. By the early 1980's, the Sierra Club and other environmental organizations were threatening lawsuits.

At this point The Nature Conservancy became actively involved. The organization had long been interested in Ash Meadows and had purchased one of the area's springs, Big Spring, in 1973. It now began to explore a number of possibilities with Preferred Equities, including the exchange of Ash Meadows land for less biologically significant property nearby, owned by the Bureau of Land Management.

The land exchange eventually was defeated by government bureaucracy, and other compromises —conservation easements and management agreements—also proved impossible. Says David Livermore, the Conservancy's representative for the Great Basin region, "It became evident that the long-term preservation of the oasis was simply not compatible with development." The only possible solution was outright purchase.

But there was a large obstacle: lack of money. Fortunately, Nevada Senator Paul Laxalt agreed to sponsor, with the Nevada congressional delegation, a bill authorizing an emergency appropriation of $5 million to allow the U.S. Fish and Wildlife Service to purchase Ash Meadows. The Conservancy would serve as an intermediary by conducting the negotiations, buying the land, and then reselling it to Fish and Wildlife. Senator Laxalt lent his support in part because the purchase was a free-market remedy that would both preserve the rare species and give the developers a fair deal.

After extensive and complex negotiations, Preferred Equities agreed to sell its 12,613 acres at Ash Meadows to The Nature Conservancy for $5.5 million, together with a $1 million loan, at 5 percent interest, made by the Conservancy at closing. The $500,000 above the Fish and Wildlife Service appropriation was allocated by the Conservancy's Katharine Ordway Endangered Species Conservation Program, which is supported by the Goodhill Foundation. The Conservancy is now working to recover this amount—which it hopes to reinvest in the area—through public and private fund raising. The $1 million for the loan was provided by the Richard King Mellon Foundation of Pittsburgh through the Conservancy's National Wetlands Conservation Project.

Now that Ash Meadows has been established as a national wildlife refuge, the U.S. Fish and Wildlife Service will most likely begin restoring damaged areas—including Carson's Slough—and developing guidelines for management and recreational use by the public. Protecting this area "has been one of the Conservancy's highest priorities for years," says David Livermore, "and we're tremendously grateful to all the people who have helped. The nice thing about the way this conflict was resolved is that the company has regained its investment, the preservation of the species has been realized, and litigation has been avoided. Everybody comes out ahead"—including the future generations of Americans who will benefit from this gem among natural areas.

With permission from the editors, this article was adapted from another of the same title appearing in *Garden,* May/June 1984, published by the New York Botanical Garden. **Anne Schwartz** is associate editor of *Garden.*

Coachella Valley's Thousand Palms

by James W. Cornett

THE SAN ANDREAS FAULT has a bad reputation. Catastrophic earthquakes along its course, though rare, are on the minds of many Californians each time a tremor shakes their neighborhood. But in Palm Springs and the Coachella Valley, the fault's reputation is improved: this enormous crack supports one of the Southwest's most scenic environments—the desert palm oasis.

With few exceptions, all of the 150 or so palm oases in the southwestern U.S. and northern Mexico occur along faults or fractures where groundwater flows to the surface. It's not surprising, then, that some of the most impressive oases are found along the San Andreas Fault, California's longest fracture and the one that runs through the heart of the Coachella Valley. The two largest oases are Willis Palms and Thousand Palms. Through recent purchases from Cathton Investments, Inc., of two parcels spanning 2,083 acres, The Nature Conservancy has acquired Thousand Palms and a vast stretch of surrounding desertland, both of which are now part of the Coachella Valley Preserve. The Conservancy also holds options to buy land to the north, east, and south of Thousand Palms, including the property that embraces Willis Palms Oasis.

Nurtured by reliable supplies of groundwater that rise to the surface at select points along a fault, the desert palm oasis is a habitat of great beauty and vitality. Cool pools of water, abundant shade, and lush vegetation stand in marked contrast to the starkness of the encircling desert. Although a wide variety of plant species exists in the oasis, it is the desert fan palm, *Washingtonia filifera,* that best typifies this habitat. Large individual trees stand up to 70 feet in height and have a diameter sometimes exceeding 40 inches. This species is the largest native palm in North America and the only one indigenous to the western United States. A few occur in Arizona and Baja California, but most are restricted to the warm Colorado Desert of southeastern California. The most spectacular groves are found near the winter resort community of Palm Springs in the Coachella Valley. Thousand Palms Oasis itself supports the second largest stand of desert fan palms on the San Andreas Fault.

Preserving such aquatic systems is critical because the Southwest now harbors less than a thousand acres of palm groves. As the region has become increasingly arid since the close of the Pleistocene, about 10,000 years ago, desert fan palms have been more and more restricted to the last remaining springs and seeps.

A relict species, the ancestors of this palm were far more abundant and more widely distributed during past geological epochs. Fossil palms have been unearthed as far north as Alaska and are scattered throughout all the deserts of North America. Palms thrived in the widespread subtropical climate of five million years ago, as did enormous herbivores such as mammoths and giant ground sloths. The palms were protected from the ravages of these predators through evolution of toothlike spines along the margins of their leaf stems. (Interestingly, once the palms had grown taller than their predators, at approximately 40 feet, they ceased producing leaves adorned with armor and relied on their height for protection.) To this day, palms below 40 feet in height still form spines, even though the giant Miocene mammals have long been extinct.

THANKS TO A GRANT from the Richard King Mellon Foundation, my co-workers and I at the Palm Springs Desert Museum have been studying the ecology of desert palm oases for the past three years. We have found that Thousand Palms Oasis (actually, there are 549 trees) is unique among palm oases in several respects. Certainly one of its most outstanding features is the abundant avifauna. As the only palm oasis with large stand-

George Service

James W. Cornett

The contrasting faces of Coachella Valley Preserve: verdant Thousand Palms Oasis (above) and surrounding dunes.

ing ponds, it acts as a magnet for migratory birds in search of a peaceful rest stop. Though we wouldn't normally associate such aquatic species as blue herons, snowy egrets, American avocets, pintail ducks, and American coots with a desert habitat, all of them have been seen frequently at Thousand Palms. In total, more than 100 bird species have been observed in the oasis; 25 are known to nest there. One species, the hooded oriole, nests almost exclusively in fan palms. Without the oasis, thousands of migratory birds would be forced to find refuge elsewhere, a remote possibility since the Colorado Desert is the hottest and driest subdivision of the North American Desert.

At least one mammal species is unique to Thousand Palms. The western harvest mouse, a three-inch rodent, is not really a desert species; but it has been able to survive at Thousand Palms, drawn by the site's aquatic habitats. Although we have live-trapped hundreds of rodents in numerous oases throughout the Colorado Desert, the harvest mouse has been found only at Thousand Palms.

The oasis is composed of three separate groves, each having its own history. Powell Palms, the smallest grove, was devastated by a flood that swept through Thousand Palms Canyon in 1979. Nearly half of its 52 trees were wiped out and much of the grove now has been replaced by smoke

trees and introduced tamarisk shrubs. The arrival of these deep-rooted perennials was partly a result of the flood's having gouged out a deeper wash channel, which caused the water table to sink. Since palms have comparatively shallow roots, those at Powell Palms are not obtaining sufficient water.

Simone Grove is a remarkably stable environment—its number of trees has changed little over the past 20 years. In 1965 there were 185; today there are 192. No fire has gone through it for at least 100 years, which (ironically) may explain the fact that the grove hasn't *increased* in size. Desert fan palms are resistant to fire. Adult trees that are burned are rarely killed and, after a conflagration, produce nearly twice as many fruits as unburned trees. Seeds dropped following a fire fall on open soil, which is moister because the flames have destroyed or burned back the transpiring plants that would otherwise intercept much of the water before it reached the surface. Thus, fire can improve conditions for palm growth.

The third stand, Thousand Palms Grove, burned in 1922 and has increased dramatically in size since that time. In 1965, 116 trees grew here. Now there are 328 individual trees—probably the densest concentration of palms anywhere in the Colorado Desert. The presence of these three groves in such close proximity, each displaying a different stage of development, offers scientists a rare opportunity to study the dynamics of palm populations.

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Hooded oriole nestlings, basket-lodged in fan palms.

EVERY TIME A STORM sends floodwater cascading into the center of the Coachella Valley, vast amounts of alluvium pass through Thousand Palms Canyon. The sand picked up by the raging waters is deposited at the canyon mouth, an area exposed to powerful winds that may reach gale proportions during spring months. The winds carry the sand and deposit it as dunes and hummocks held by creosote scrub just two miles from Thousand Palms Oasis.

This dune environment is the antithesis of the palm oasis. There is little shade, scant vegetation, and no water. It is hard to believe that both the dunes and the oasis are considered desert habitats. Nevertheless, they are inexorably related. Both are children of the San Andreas Fault. The fault is responsible for the natural seeps that enable the palms to flourish, and it is also the fault's movements that have formed Thousand Palms Canyon —the source of the dune sand. Moreover, San Andreas "created" the San Gorgonio Pass, ten miles to the west, which funnels the winds that move the sand over large distances.

Just as certain animal species are closely linked to the oasis environment, others are restricted to the dunes. In fact, one creature is so closely associated with the sand dunes that it can exist nowhere else. With the rapid urban development of the Coachella Valley, this animal is running out of both time and space. It is the Coachella Valley fringe-toed lizard (*Uma inornata*)—a splendid example of a species totally adapted to its surroundings. The reptile's common name is derived from the fringe-like scales on its toes, which increase the surface area of its feet and improve the lizard's traction on the loose-shifting sands. The scales swivel at their point of attachment, splaying outward as the lizard pushes back with its foot and flexing inward against the toes as it draws its foot forward. Thus, *Uma* is able to move rapidly over and under the sand. When a predator approaches—either a roadrunner, a kestrel, or a human—the lizard runs off with electrifying speed then suddenly dives headfirst into the sand, leaving only a small V-like depression. Most predators never see *Uma* disappear into the substrate, so they wander off in search of less elusive prey.

Because sand grains have an insidious way of entering every opening and crevice in an animal's body, the fringe-toed lizard has evolved both structures and behavior that keep sand out. Its nostrils bear a U-shaped sand trap that allows air to pass through the spaces between sand grains

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The nationally threatened Coachella Valley fringe-toed lizard (above) and its quick-traction fringed toes (inset).

but prevents sand from traveling farther up the passageways. When *Uma* emerges, it "sneezes" violently to blow out the grains that entered the forward portion of the trap. The eyes are protected by overlapping lids, which act as a double seal. Any sand that manages to penetrate these structures accumulates at the front corner, where it is encased in mucus and then expelled. Flaps in front of its ears fold back over the ear canals during submergence, effectively keeping sand out. In addition, a countersunk lower jaw prevents the lizard from taking in a mouthful of sand when it dives. The under jaw fits completely into the upper one, thereby creating a tight seal that thwarts the entrance of even the tiniest grains.

Uma has adapted not only to its sandy surroundings but to a lack of sufficient water as well. The dunes are perpetually dry; "drinking water" is simply nonexistent. For the fringe-toed lizard, the answer is obvious: it must obtain all the moisture it requires from the foods it eats. Although it is largely carnivorous—feeding on beetles, ants, grasshoppers, scorpions, caterpillars, and occasionally other lizards—*Uma* sometimes consumes buds, fruits, leaves, and seeds.

RAPID URBAN DEVELOPMENT in this popular Palm Springs resort area is now threatening the reptile's continued existence in its only known habitat. Condominiums are being built in ever-growing numbers on what was once fringe-toed lizard territory. To arrest this trend, the federal government declared *Uma inornata* a threatened species in 1980, with the State of California doing the same in 1981.

Fortunately, of the land already secured for the Conservancy's Coachella Valley Preserve, a portion supports an extraordinarily high concentration of fringe-toed lizards. The Nature Conservancy—working with the California Department of Fish and Game, the U.S. Fish and Wildlife Service, the Bureau of Land Management, and local developers and citizens—will be acquiring more prime dune habitat for *Uma*. These lands, too, will be incorporated in the oasis preserve. When the assemblage is complete, there will be much for conservationists to applaud: full protection of Coachella Valley's last undisturbed watershed, with its large groves of desert fan palms, and several thousand acres of windblown dunes. The San Andreas Fault never looked so good.

Jim Cornett is curator of natural science at the Palm Springs Desert Museum in Palm Springs, California. In addition to observing members of the genus *Uma*, he is studying desert palm oases throughout the world. He is the author of *Wildlife of the Western Mountains* (Nature Trails Press, 1982).

ECOLOGY FORUM

No. 54

by William W. Dudley, Jr.
Hydrologist
U.S. Geological Survey
Denver, Colorado

THE HYDROLOGY OF ASH MEADOWS

Desert hydrologic systems, like the desert aquatic ecosystems they foster, are fragile. Long-term protection of the extraordinary fauna and flora found in such desert wildlands as Ash Meadows, in southern Nevada, may depend on maintaining a delicate stability in a groundwater system far from the site itself.

Ash Meadows became a center of controversy in the late 1960's, when a team of federal, state, and university biologists recognized that the increasing use of groundwater for irrigation in the area threatened the survival of several species of desert pupfish. Most critically endangered was the Devil's Hole pupfish, *Cyprinodon diabolis*. The water level was declining in the isolated sinkhole that is the sole habitat for this small fish, gradually exposing the shallow rock ledge upon which the fish depend for both breeding and feeding.

An intensive study of the area, which I conducted with J. D. Larson, was commissioned in 1970 by the Department of the Interior's Desert Pupfish Task Force. The results, published in 1976 by the U.S. Geological Survey,[1] provide convincing evidence that most of the wells operated between 1969 and 1972 at Ash Meadows by the Spring Meadows, Inc., ranch caused either a decline of the water level in Devil's Hole or decreases of flow from the major springs.

However, the local hydrologic system at Ash Meadows proved to be too complex for us to predict in detail the effects of pumping at locations other than those we actually observed during the study. For example, pumping of one well in southern Ash Meadows scarcely affected wells and springs within several hundred feet but produced an immediate decrease of flow in Jack Rabbit Spring, more than a mile away. Within hours of pumping, the springflow there was completely arrested. Pumping at other wells in the same field affected neither the first well nor Jack Rabbit Spring and had only minimal effects on nearby springs—but it produced a distinct decline in the water level of Devil's Hole, more than two miles away.

Pumping at Ash Meadows stopped in 1976 after the Supreme Court upheld an earlier U.S. District Court requirement for a minimum allowable water level in Devil's Hole. The Devil's Hole water level and flows of the affected springs began to recover and are now virtually restored. Nonetheless, the judicial decisions did not address springflows nor the potential effects of withdrawing groundwater at areas away from Ash Meadows itself. In order to understand the issues of springflow and distant pumping, we must first examine the hydrologic relationship between Ash Meadows and the southern Great Basin.

Because the region surrounding Ash Meadows is arid to semiarid, state and federal agencies have conducted or sponsored extensive research related to both the development and the protection of its scarce water resources. In the early 1970's, Isaac J. Winograd and William Thordarson compiled the results of their own research with virtually all the results of earlier studies by federal and state agencies, universities, and private organizations and individuals. Their compendium[2] is still the authoritative source of data and hydrologic interpretation for the southern Great Basin.

The water that emerges in the springs at Ash Meadows has been in transit underground for thousands of years in a huge groundwater system or basin that extends about 100 miles to the north and about 60 miles to the east. The groundwater in this system is replenished by rainfall and snowmelt in the higher mountain ranges and mesas, such as the Spring Mountains east of Ash Meadows, the Sheep Range at the eastern edge of the groundwater basin, the Pahranagat and Tempahute Ranges at the northeastern extreme, and the Belted Range

and Rainier Mesa to the north. Within this area of about 4,500 square miles are several lower ranges and dry valleys that are separated by large faults along which rocks have been displaced thousands of feet. Many more faults segment the ranges and are buried beneath the thick sediments that fill the valleys.

A thickness of several thousand feet of limestone and dolomite—formed between 250 million and 500 million years ago—constitutes the regional carbonate aquifer (a permeable, water-bearing stratum) in this vast groundwater basin. Groundwater moving through these rocks has slowly dissolved minute portions of the mass, widening fracture openings and, at places, developing conduits several feet across. If this very permeable aquifer were continuous over the region, it would easily transmit the available water to the ultimate regional discharge area in Death Valley. Its nearly flat water table would be too deep to intersect the land surface at intermediate points such as Ash Meadows. However, many faults disrupt the aquifer's continuity, forming underground "dams" that impede flow or restrict it laterally.

About 15 miles northeast of Ash Meadows, virtually all of the flow in the groundwater system is channeled through a five-mile-wide gateway between the older, nearly impermeable rocks of the Spring Mountains and the Spectre Range. Continuing southwestward beneath a broad desert valley, the flow is impeded by one or more faults along the eastern side of Ash Meadows. "Ponded" behind these faults, some of the water is forced to surface in the lower parts of the bedrock hills. Most of the flow, however, seeps through the leaky faults into the young sediments that flank the hills, emerging at the lower-altitude springs of the Ash Meadows oases.

Thousands of years ago—during the pluvial, or wetter climates that prevailed in this area in the Pleistocene Epoch—groundwater rose higher behind the faults, and a greater proportion of the flow issued directly from the regional aquifer. Devil's Hole was one such spring, feeding a stream that flowed westward to the Amargosa Basin. Other springs at lower altitudes discharged through pathways lengthened by accumulating sediments and travertine (calcium carbonates) precipitated from the springflows themselves.

Springflow at Devil's Hole ceased sometime during the Pleistocene, possibly leaving stranded the ancestors of the present Devil's Hole pupfish. Springs at successively lower altitudes also ceased flowing or else declined in flow to the extent that the discharge was entirely consumed by plants and evaporation, isolating yet other populations of fishes.

Whether the cause of decreased springflow was increasing aridity, uplift of rocks that were previously below the water table (as suggested in a second study by Isaac J. Winograd and Gene C. Doty[3]), or a combination of the two, one conclusion is inescapable. The hydrology and, thus, the unique ecology of the Ash Meadows area have changed significantly within the past several tens of thousands of years. We can expect that additional significant changes will occur over similar periods in the future.

Within a time period more easily comprehended by humans, how can we predict the impacts of drawing water from the regional aquifer beyond the boundaries of Ash Meadows? The complexities of hydraulic interconnections that we observed during the pumping tests force us to look for other lines of evidence. Fortunately, proof is provided by the chemistry and temperature of the springs' waters, which are less capricious than the local geologic "plumbing." The eight major springs together release more than 9,000 gallons per minute, whereas the cumulative flow from about 25 other springs and seeps is less than 2,000 gallons per minute. These major springs produce water that is remarkably uniform in chemical characteristics, and the composition is the same as that of water taken from wells that penetrate the regional aquifer to the east and northeast.

Water that emerges from or very close to the carbonate rocks, which form low hills just east of southern and central Ash Meadows, is quite warm (90° to 94°F), indicating that the approaching flowpaths are deep. The major springs west of these hills also yield relatively warm water, although their temperatures decrease with increasing distance from the regional aquifer and with decreasing flow rates.

In contrast, the three major springs (Fairbanks, Rogers, and Longstreet) in northern Ash Meadows yield relatively cool (82° to 84°F) water, considering their large discharges and their proximity to the regional aquifer. There is evidence that these springs may be supplied by shallow flowpaths from the northeast or north.

Pumping of groundwater from the regional aquifer—particularly water with a temperature over 90°F—to the east or northeast of Ash Meadows would cause a declining water level in Devil's Hole and a reduction of spring discharge in central and southern Ash Meadows. Pumping to the northeast and north would quite likely decrease flows of the three major springs in northern Ash Meadows, especially if the water pumped were in the range of 82° to 88°F. We can only speculate as to the degree of interconnection between the shallower, cooler flowpaths and the deeper, warm-

er ones. The geologic setting and the chemical uniformity of the water, however, indicate a common source.

Should pumping be sufficiently intense and the duration sufficiently long, perhaps decades, effects on Devil's Hole and all of the major springs at Ash Meadows would be inevitable. The Ash Meadows groundwater system is presently in apparent equilibrium, discharging at a near-constant rate. Ultimately, sustained pumping from the system would cause lowered water levels in the regional aquifer, in turn causing decreased springflow. Thus, the stability of the habitats of the endemic flora and fauna at Ash Meadows is inextricably intertwined with that of the regional aquifer perhaps tens of miles away. This fact must be weighed heavily when considering exploitation of the groundwater that gives life to this uncommon desert habitat.

* * *

[1] *U.S. Geological Survey Professional Paper 712-C,* 1975.
[2] *U.S. Geological Survey Open-File Report 80-569,* 1980.
[3] *U.S. Geological Survey Professional Paper 927,* 1976.

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FIELD COURSES OFFERED IN THE PACIFIC NORTHWEST

Lying at the interface between Oregon's Cascade Range and the Great Basin, the Conservancy's Katharine Ordway Sycan Marsh Preserve will be the site next June and July (1985) of beginning and advanced seven- and ten-day field courses. Studies will embrace botany, general natural history, and ornithology. Excursions will take in vast alkaline lakes, volcanic mountains, sage deserts, forests of pine and fir, and freshwater marshes hosting some 200 breeding greater sandhill cranes.

Transportation, meals, and facilities (tents) for staff and nine participants per session will be provided. Cost: seven-day/$700, ten-day/$850. For further information, contact: Sycan Education, The Nature Conservancy, 1234 N.W. 25th Avenue, Portland, Oregon 97210. Phone: (503) 228-9561.

NEW PROJECTS

CALIFORNIA

Coachella Valley Preserve—Additions—(Riverside County). Two purchased tracts spanning 2,083 acres support a rare combination of desert habitats: Thousand Palms Oasis, which boasts one of the state's largest groves of increasingly scarce desert fan palms (*Washingtonia filifera*), and surrounding sand dunes—critical habitat for the nationally threatened Coachella Valley fringe-toed lizard (*Uma inornata*). Charted for protection through the Conservancy's National Wetlands Conservation Project, the present 2,083-acre preserve is a fine start for a projected 13,000-acre assemblage. Coachella Valley Preserve is managed by the Conservancy's California Field Office. (See article beginning on page 18.)

Desert Tortoise Preserve—Addition—(Kern County). Since 1976 the Conservancy has been working to extend habitat protection for the Mojave Desert's state-protected desert tortoise (*Gopherus agassizi*). Its holdings within the 45-square-mile Desert Tortoise Natural Area currently stand at 1,540 acres, including two recent purchases totaling 60 acres. The preserve's rich creosote scrub plant community (with more than 160 vascular plant species) sustains some 200 tortoises per square mile, an unusually high concentration. It also harbors the Mojave ground squirrel, ranked as rare in California. Founded by Dr. Kristin Berry, lead zoologist and wildlife biologist for the Bureau of Land Management's California Desert Program, the Desert Tortoise Preserve Committee manages the refuge.

Paine Preserve—Additions—(Kern County). A 240-acre purchase enlarges the sanctuary, a mosaic of valley saltbush scrub and alkaline vernal pools—two ecosystems targeted for protection by the California Natural Diversity Data Base. Three species endemic to the San Joaquin Valley are found here: alkali larkspur, blunt-nosed leopard lizard, and San Joaquin kit fox. Both the lizard and the fox are endangered nationwide. A project of the now-completed California Critical Areas Program, the 600-acre refuge is managed by the Conservancy's California land steward.

MARYLAND

John Friend Cave (Garrett County). If you lean over the cavern's opening, you can feel the cool air escaping. Fifteen feet below, John Friend Cave stretches more than 1,000 feet—one of the deepest caves in Maryland. First explored in the early 1700's, it is a haven for three species of arthropods and for small-footed bats (*Myotis subulatus leibii*), all rare in the state. A small number of Indiana bats, federally listed as endangered nationwide, frequent the cave during summer months. A recently purchased nine-acre parcel protects the cavern's entrance. Targeted by the Maryland Natural Areas Campaign, the preserve will be managed by the Maryland Chapter.

Hammel Glade (Garrett County). Nestled between high ridges on the Allegheny Plateau, Hammel Glade bears one of the most botanically diverse mountain peatlands of its type in the region. A dense patchwork of plant communities occurs here, including Maryland's largest red-spruce forest. At least seven plant species rare in the state—and one candidate for federal listing—thrive in the glade's moist soils. Sharp-shinned hawks (*Accipiter striatus*) and alder flycatchers (*Epidonax alnorum*), both rare breeding birds in the state, nest at the site. The purchase of 78 acres is the Conservancy's first acquisition at Hammel Glade, a protection target of the $1.5-million Maryland Natural Areas Campaign. The Maryland Chapter will manage the preserve.

Nassawango Creek—Addition—(Worcester County). This 113-acre gift of James S. Onley, Sr., links existing Conservancy holdings along the 15-mile corridor of Nassawango Creek, a tributary of the blackwater Pocomoke River on Maryland's Eastern Shore. Now spanning 2,366 acres, the sanctuary encompasses a bald cypress/sweet gum swamp—home for some 17 warbler species. A vestige of the towering bald cypress forests that greeted the first settlers, the preserve is managed by the Conservancy's Nassawango Creek Stewardship Committee.

MINNESOTA

Western Prairie North—Addition—(Wilkin County). With a 40-acre purchase, the Conservancy has increased its acreage at this grassland preserve to 320. Encompassing a native wet-mesic tallgrass prairie, the sanctuary provides habitat for five

species listed by the state as rare: gentian, prairie vole, marbled godwit, upland sandpiper, and greater prairie chicken. Controlled burning of the grassland is used to enhance species diversity and check the intrusion and spread of exotic species. Cooperatively managed by the Conservancy's field office and the Minnesota Department of Natural Resources, the preserve has been leased to the department and designated as a scientific and natural area.

MISSISSIPPI

Buttercup Flats (Hancock County). Hosting an orchid (*Pteroglossastis ecristata*) and a holly (*Ilex amelanchier*) that are candidates for federal listing, this 70-acre purchase bears several habitats: savanna, bog, bay swamp, and long-leaf pine forest. The small bog, which lies at the bottom of a bowl-shaped depression of land, harbors a species of bog button—a plant ranked by the Mississippi Natural Heritage Program as threatened in the state—as well as a fine population of pitcher plants. The mouth of the "bowl" merges with savanna on one side, bay swamp on the other. A protection priority of the Conservancy's Katharine Ordway Endangered Species Conservation Program, funded by the Goodhill Foundation, the preserve will be managed by the Crosby Arboretum and the Southeast Regional Office.

MISSOURI

Nancy B. Altvater Pondberry Preserve (Ripley County). Through a 100-acre purchase, the Conservancy has protected a highly uncommon sand pond, a natural community found only in two Missouri counties. The site's forested swampy depressions support corkwood (threatened in the state), pin oak, willow oak, sweet gum, bald cypress, and swamp red maple. Its swales and their associated sandy dunes, formed by glacial outwash at the end of the Pleistocene, harbor pondberry (*Lindera melissifolium*), a shrub ranked by the Conservancy as globally endangered and proposed for federal protection as well. Today only five populations exist. The property will be managed by the Missouri Department of Conservation within its nearby Sand Pond Natural Area. It is the first in a series of acquisitions throughout the state to be named in memory of Nancy B. Altvater.

Marmaton River Bottoms—Addition—(Vernon County). The purchase of 40 acres brings further protection to Marmaton River Bottoms, the largest tract of wet prairie remaining in southwestern Missouri. A project of the Conservancy's National Critical Areas Conservation Program, the 290-acre preserve hosts northern harriers—endangered in Missouri—as well as great blue herons, grasshopper sparrows, and meadow mice. The Missouri Chapter manages the sanctuary with assistance from the Missouri Department of Conservation.

Mo-No-I Prairie (Barton County). Working with the Missouri Department of Conservation, the Conservancy purchased 160 acres of high quality virgin tallgrass prairie. The site harbors a large population of greater prairie chickens (*Tympanuchus cupido*), a species endangered throughout the state. Three "booming grounds," where the plump birds court and mate, lie only a quarter of a mile from the preserve. Well-established irrigation ponds attract migrating waterfowl, such as snow geese and white pelicans. Mo-No-I Prairie, which bears the Osage Indian name for prairie chicken, will be managed by the Department of Conservation.

NEW YORK

Accabonac Harbor—Addition—(Suffolk County). The Conservancy has acquired a key eight-acre inholding in the southernmost portion of its 136-acre tidal marsh preserve. Adjoining a 1,000-acre estuary, the preserve hosts 158 bird species, including nesting ospreys and migrating peregrine falcons. Its waters provide overwintering ground for harbor seals and a nursery for nearly 100 aquatic invertebrate species. Accabonac Harbor is managed by the Conservancy's South Fork-Shelter Island Chapter.

Carncross Salt Pond (Wayne County). This natural inland salt pond and surrounding salt marsh in central New York are considered the state's best examples of two community types ranked as endangered by the Conservancy's New York Natural Heritage Program. Characteristic native halophytes (plants thriving in salty soils) are found in the marsh: *Atriplex patula, Spergularia marina,* and *Eleocharis parvula. Ruppia maritima* grows in the salt pond. The Conservancy has purchased the first 64 acres for a projected 130-acre preserve. A project of the Conservancy's National Critical Areas Conservation Program, the site will be managed by the Central New York Chapter and the New York Field Office.

Zipfelberg Bog—Addition—(Dutchess County). Zipfelberg embraces five different vegetational associations, including a 15-acre red maple/hemlock swamp with a six-acre sphagnum bog lying at its center. Fringed by Virginia chain fern and acid-loving shrubs, the bog is a filled-in kettlehole pond with a thick mat of sphagnum moss supporting several bog-specific plant species: rose pogonia, white-

Gary Meszaros

Showy lady's-slippers

Fern Ridge Preserve

Picture Iowa and you'll probably conjure up level farmland or gently rolling hills. But at the newly established Fern Ridge Preserve in the northeastern part of the state, just west of the Mississippi River, you're in for a surprise: sheer limestone bluffs towering 60 feet above a small creek.

On certain portions of the area's north-facing talus slopes, cold air seeps from fissures in the limestone bedrock. The resultant year-round temperature—a cool 50 degrees F in summer and 14 degrees F in winter—fosters the growth of balsam fir trees and other plants usually found farther north. Two of these, dwarf scouring-rush (*Equisetum scirpoides*) and limestone oak fern (*Gymnocarpium robertianum*), are endangered in the state.

In addition to this wealth of glacial relict flora, the slopes harbor a living fossil—a snail once thought extinct. Early in this century, scientists knew of the tiny (six- to eight-millimeter) creature only from fossil records in the Midwest. They were astounded when, in 1940, a naturalist reported locating shells of the snail in a collection at the Smithsonian Institution in Washington, D.C. The find sparked an effort to locate the living species. In 1955, geologists rediscovered the snail on an Iowa site. Since 1980, some 16 additional locations—including the Fern Ridge Preserve—have been found in the state, another in Illinois. Perhaps only 25 acres provide all the known habitat for this snail, which is federally listed as endangered throughout its range.

A recent purchase of 143 acres by the Conservancy protects this extraordinary habitat and essential bufferland. A project of the Conservancy's Katharine Ordway Endangered Species Conservation Program, the area will be managed by the Iowa Chapter. It is slated for designation as a state nature preserve.

fringed orchis, grass pink, round-leaved sundew, and pitcher plant. Limestone cliffs rising high above the wetland bear locally rare purple-stemmed cliffbrake and wall-rue. A 23-acre purchase takes in the major portion of the bog and adjacent cliffs. The 37-acre preserve is managed by the Lower Hudson Chapter.

OHIO

Arcola Creek—Addition—(Lake County). Between 1954 and 1974, almost 65 percent of the riverine marshes along Lake Erie's shoreline were lost to development. Arcola Creek is one of the last remaining stream mouths along Lake Erie where a submerged riverine marsh persists. The Conservancy recently purchased two parcels totaling 14 acres along the creek, bringing its preserve acreage here to 43. The addition hosts the leafy tussock sedge (*Carex aquatilis*), a plant endangered in the state. A major objective of the Conservancy's now-completed Ohio Lands Forever Campaign, Arcola Creek also harbors inland beach pea, threatened in Ohio, as well as sea rocket, seaside spurge, and purple sandgrass—all state-listed as potentially threatened. The Ohio Field Office will coordinate management of the area.

PENNSYLVANIA

Tannersville Cranberry Bog—Addition—(Monroe County). Walk across the boardwalk here in August and find welcome relief from the heat. Located in the Pocono Mountains, this glacial remnant is one of the finest examples of a black spruce/tamarack bog in Pennsylvania. A purchased 75-acre addition of upstream bufferland brings the preserve to 419 acres—habitat for ten species of orchids (one endangered in the state, another threatened), two sedges state-listed as threatened, and the rare bog copper butterfly. The Tannersville Cranberry Bog Preserve Committee, which manages the sanctuary, and the Pennsylvania Field Office are raising $60,800 for the new parcel.

VERMONT

H. Laurence Achilles Natural Area—Addition—(Chittenden County). The H. Laurence Achilles Natural Area at Shelburne Pond now encompasses some three-quarters of the largest undisturbed pond and wetland complex in northwestern Vermont. A proposed national natural landmark, the pond is a wilderness lake only six miles from Burlington. With the recent purchase of two parcels embracing 94 acres, the Conservancy has now protected 731 acres here. These additions were funded by an earlier donation from H. Laurence Achilles for acquisitions at Shelburne. The preserve, which also bears at least a dozen Indian archeological sites, is managed by the University of Vermont.

VIRGINIA

Gasburg Granite Flatrock Preserve (Brunswick County). This 14-acre purchase bears one of Virginia's few known granite outcroppings—three large flatrocks separated by field and xeric oak-pine woods. However, the site's greatest significance lies in the plant community that thrives in the shallow soil held by depressions in the granite. This lilliputian community includes three plant species endangered in the state: a sedge, a stonecrop, and a portulaca. It is the only known location in Virginia where the three species co-exist. A project of the Conserve Virginia Campaign, Gasburg Granite Flatrock will be managed by the Virginia Chapter.

WISCONSIN

Baraboo Hills Project/Baxter's Hollow: the R. D. and Linda Peters Nature Preserve—Addition—(Sauk County). Well-known in the Midwest for its water purity, Otter Creek in the Baraboo Hills is a cold-water trout stream used extensively for aquatic invertebrate research. A 40-acre purchase extends protection to the northwest corner of Otter Creek's watershed—the only undeveloped watershed in southern Wisconsin—and to a set of springs essential to the creek's preservation. The addition also includes a mature stand of southern dry forest, habitat for a variety of nesting songbirds. Now totaling 1,732 acres, the sanctuary is managed by the Conservancy's Wisconsin Chapter.

NEW GOODHILL GRANT ANNOUNCED

The Conservancy has received a final challenge grant from the Goodhill Foundation of New York to extend the ambitious National Critical Areas Conservation Program. Undertaken in 1980 to protect the most endangered natural systems in the United States, the program's $30-million first phase came to a successful close last December. The Conservancy had met and surpassed the two-to-one challenge from the Goodhill Foundation and had safeguarded 48 nationally critical sites embracing 192,000 acres. In the program's exciting second phase, the Conservancy must raise $15 million to match the new grant three to one.

Oak Leaf Awards 1983

Once a year The Nature Conservancy acknowledges the outstanding efforts of its members through the presentation of the Oak Leaf Awards. This award, symbolized by a green and gold lapel pin, is given in recognition of especially dedicated service and support toward achieving the Conservancy's objectives.

George E. Allen has been a member of the Conservancy since the mid-60's, serving as chairman of the Florida Chapter from 1975 to 1978. A current trustee, Mr. Allen was responsible for the acquisition of a number of important preserves and for the formation of the Chapter's Mahogany Club for donors of over $100.

Frank D. Boren has been a tremendous force for the Conservancy both in California and nationally. As chairman of the recognized California Chapter, he brought together leaders in the science, business, and civic communities to focus on statewide land-protection goals. He encouraged the planning of the succcessful California Critical Areas Program and worked to protect Santa Cruz Island, the largest of the California Channel Islands. Nationally, he served on the Board of Governors, both as a member and as chairman, and was the driving force behind the development of the Trade Lands and Corporate Associates programs.

A charter member of the West Virginia Chapter, **Eleanor Mockler Bush** used her biology background to identify crucial habitats—two of which are now registry sites—and to conduct botanical surveys of preserves and trade lands. She served as chairman of the chapter from 1977 to 1980 and continues to support the Conservancy, presenting slide shows to civic groups and locating sites for rare species.

Wayne H. Byrne has served as chairman of the Adirondack Conservancy Committee since its creation in 1971. Under his leadership, the committee has protected close to 100,000 acres of land in the Adirondack region. He personally spearheaded the drive for a number of projects including Valcour Island and Bay Pond Park.

As chairman of the Eastern Pennsylvania Chapter from 1980 to 1984, **Thomas Dolan IV** worked to establish a Pennsylvania heritage program and to acquire seven critical additions to five Pennsylvania preserves. Under his leadership, the chapter concluded its most ambitious campaign to date, raising $480,000 for the Pennsylvania Land Protection Program.

John H. Filer has provided valuable business expertise to the Conservancy as a member of the national Board of Governors and national Corporate Relations Committee. In addition, he has been one of the Conservancy's strongest representatives to the corporate community. Thanks to his assistance, annual corporate support has more than doubled since 1978.

Irene Speros Herlocker accomplished what seemed impossible—she saved Hoosier Prairie from development. The 300-acre preserve in Indiana protects over 300 native species of vascular plants. A member of the Indiana Chapter Board since 1979, Mrs. Herlocker has used her interest in botany to develop plant lists for the prairie and has assisted in numerous other Indiana projects.

Hadlai A. Hull used his financial management experience to turn the Conservancy's financial position around. During his seven years as volunteer director of finance, the Conservancy's endowment grew from $5.7 million to over $15 million. In addition to his contributions in finance, he provided invaluable guidance to the Conservancy's overall management as a member of the Core Management Group.

As a member of the national Board of Governors from 1975 to 1980, **Dan W. Lufkin** of Connecticut was a respected business advisor to the Conservancy. In 1978 he helped launch the Conservancy's Corporate Relations Committee and served as co-chairman. Since that time Mr. Lufkin's efforts have led to substantially increased corporate support of the Conservancy.

As co-chairman of the California Critical Areas Program Committee, **David Packard** of California was instrumental in the successful effort to raise $15 million to protect the state's 11 most threatened ecosystems. He continues to support the Conservancy by serving as vice-chairman of the newly reorganized California Chapter Board of Directors.

As one of Wisconsin's most dedicated volunteers, **John R. Shaw** used his business expertise to revise the chapter's accounting system. After serving on the Wisconsin Chapter Board from 1978 to 1981, Mr. Shaw was elected chairman. From 1981 to 1984 he led the Wisconsin Chapter through the greatest period of growth in its 20-year history.

Aileen Bowdoin Train has been a strong supporter of the Maryland Chapter, serving as chairman from 1982 to date. She led the chapter to the successful completion of a number of campaigns including a $135,000 drive

to protect Nanjemoy Creek and an $820,000 effort for Nassawango Creek. She has also been a major force behind the nearly completed $1.2 million Maryland Natural Areas Campaign.

R. E. "Ted" Turner has been a strong supporter of the Conservancy for many years. He has served as a member of the Conservancy's national corporate relations committee and has donated his time to helping the South Carolina program. This year Mr. Turner donated the development rights on St. Phillips Island to the Conservancy, helping to protect one of the most pristine islands remaining on the east coast.

A 1967 field trip to a cave sparked **Dr. John E. Warnock's** interest in conservation. The driving force behind the protection of Cedar Glen Eagle Roost, one of the most significant winter roosting sites for bald eagles in the nation, Dr. Warnock has assisted with a number of other important projects. For the past nine years he has provided scientific consultation to the Illinois chapter board.

David R. Wintermann has been one of the most loyal supporters of the Texas program. He donated property to protect the Conservancy's first Texas project, Atwater Prairie Chicken National Wildlife Refuge, and assisted in the preservation of McFaddin Ranch. His energetic support includes hosting Conservancy functions and representing the Conservancy to Texas government.

International Award Winner: John S. Dunning has been a key person in the Conservancy's international conservation efforts. Together with his wife, he established the John S. and Harriet Dunning Neotropical Land Conservation Fund, a $200,000 fund for preserving endangered bird habitat in South America. He has worked closely with the Conservancy's international office for a number of years, providing advice and referrals to potential donors and supporters. An avid photographer, Mr. Dunning has published three books on tropical birds.

Stewardship Awards

Each year the Conservancy honors a committee and individuals who have contributed significantly to the advancement of the science of stewardship on Conservancy preserves.

Fifteen years ago the Minnesota Chapter, recognizing the need to adequately manage the growing number of sanctuaries being brought under Conservancy ownership, established the **Minnesota Chapter Preserve Management Committee.** The committee has a long history of accomplishments and serves as a model for other state stewardship programs. The current committee has developed a long-range plan and has completed stewardship plans for each of the state's 68 preserves.

Dr. Edward B. Seligmann, Jr., vice chairman for stewardship for the Maryland Chapter, has directed the chapter's time and resources to the state's most important elements and sites. He spearheaded an effort to develop a comprehensive management plan for Nassawango Creek. Through his involvement in preserve and state stewardship planning, Dr. Seligmann continued to demonstrate his commitment to achieving the Conservancy's long-term goals.

In her 22 years of membership on the Wisconsin Chapter Board of Trustees, **Emily H. Earley** has demonstrated a remarkable commitment to protection and care of Wisconsin's natural resources. She has been a full-time volunteer since her association with the Conservancy began and has been the guiding light in the planning and implementation of the chapter's stewardship endeavors. Mrs. Earley is recognized for her effort in building and sustaining the chapter's stewardship program.

President's Public Service Awards

Over the years, many people outside the Conservancy's immediate family of volunteers and staff have become valued friends and have helped the Conservancy greatly in achieving its ambitious objectives. To recognize some of the most outstanding of these outstanding people, the President's Public Service Award has been created.

Walter R. McAllester has long been a good friend and loyal member of The Nature Conservancy. As chief of the Division of Realty for the U.S. Fish and Wildlife Service, Mr. McAllester is responsible for the creation of new wildlife refuges and the acquisition of additional lands to complete existing refuges. Sevilleta de la Joya in New Mexico, the Lower Suwannee in Florida, the Texas Gulf Coast marsh refuges, the Bon Secour Natural Wildlife Refuge in Alabama, and the Great Dismal Swamp in Virginia and North Carolina are just a few of the many significant natural areas that have been added to the National Refuge System thanks to Walt McAllester and his fruitful cooperation with The Nature Conservancy.

Mr. McAllester's counterpart at the U.S. Forest Service is **Vernon V. Lindholm,** another good friend and loyal member of the Conservancy. As assistant director of lands for the Forest Service, Mr. Lindholm has worked very effectively with the Conservancy over the last ten years. During that time he guided the Service in the acquisition of land valued in all at over $50 million. This has resulted in the protection of important natural areas from the Appalachians to the Rocky Mountains.

NEW LIFE MEMBERS

An individual becomes a Life Member of The Nature Conservancy upon contribution of $1,000 for membership dues or for the Land Preservation Fund, Guarantee & Income Fund, or a State Land Preservation Fund. Husbands and wives may hold a joint life membership for a single qualifying contribution.

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A corporation becomes a Corporate Associate of The Nature Conservancy upon contributing between $1,000 and $10,000 annually to the operations of the organization.

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